WATERPROOF MARINE VENTILATION SYSTEM FOR DRY FREIGHT VAN CONTAINERS

MARKETING RESEARCH REPORT NO. 988

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

This study is part of a broad program of research by the Agricultural Research Service on the problems of shipping agricultural commodities to overseas markets.

The "K" Line Company of Tokyo, Japan, supplied the van container used in this study. Seald-Sweet Growers, Inc., Tampa, Fla., and A. Duda and Sons, Ovieda, Fla., supplied the test loads of grapefruit and watermelons, respectively. United States Lines, New York, provided ocean transportation of researchers to accompany the loads. Great Dane Company, Savannah, Ga., supplied some material and technical advice on van container modification.

Special credit is due Russell H. Hinds, Jr., International Programs Division, Agricultural Research Service, who laid the preliminary groundwork for this research and who also collected data and supplied technical advice, and Lawrence A. Risse, Southern Region, Agricultural Research Service, who assisted with the watermelon tests.

CONTENTS

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WATERPROOF MARINE VENTILATION SYSTEM FOR DRY FREIGHT VAN CONTAINERS

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SUMMARY

A waterproof marine ventilation system for dry freight van containers was developed for overseas transportation of commodities requiring moderately low temperatures. This new system incorporates a "marine plug," which allows air to enter but keeps seawater out of the cargo compartment. In addition to the marine plug, electrically powered exhaust blowers are mounted on the rear doors to pull air into the front of the van container and through the load.

The arrival condition of an overseas shipment of grapefruit transported in a dry freight van container equipped with the waterproof marine ventilation system was as good as that of grapefruit transported in the refrigerated van containers shipped at the same time. There was no damage to boxes or fruit shipped in the ventilated van container, whereas some boxes were damaged in the refrigerated van containers, mostly because moisture weakened the boxes.

Watermelons shipped from Florida in the same ventilated van container, with modifications, arrived in England in good condition with only 2-percent loss. Subsequent loads shipped in refrigerated van containers suffered 18.5-percent loss. However, this high loss was attributable in part to shipping overmature watermelons and using weaker single-wall fiberboard boxes.

The ocean freight rate for shipments in the ventilated van containers should be approximately 10 percent less when this type of service becomes available according to industry officials. In addition to lower freight rates, about 10 percent more cargo can be loaded in the ventilated than in the refrigerated van containers because of their larger interior and their lower tare weight.

Additional research is needed to develop further refinements in the air control and exhaust systems.

INTRODUCTION

Containerized shipping requires large numbers of refrigerated as well as dry freight van containers for transporting cargo overseas. Refrigerated van containers are used to control temperature of perishables as well as such products as computers and electronic components, which are not "perishable" in the sense that they would rot or decay if not kept under refrigeration. Perishable products, i.e., frozen foods, meats, fruits, and vegetables, all compete for refrigerated containers along with those products that are not "perishable." A 700-foot container ship capable of carrying 900 to 1,000 20-foot equivalent containers may have

space for only 80 to 90 40-foot-long refrigerated van containers. Consequently, all products requiring refrigeration compete for these relatively few spaces.

Because of the high costs of owning and operating refrigerated van containers, the ocean carriers try to hold their refrigerated fleet to a minimum, further tightening the supply of this type of equipment to the shipper. Fruits and vegetables carry a low priority on refrigerated container availability since the other products generally are carried at higher freight rates and are less susceptible to damage and claims.

Several perishable products can be safely transported to overseas markets using the ambient or outside air for cooling when the ambient air is at, or slightly below, optimum transport temperature for the product. These are products that can be protected at 40° to 60° F. (table 1). A study of the climatological data shows that the air temperature on the North Atlantic Ocean during October, November, early December, March, April, and May (fig. 1 and table 2) are within the ranges required by most products listed in table 1. The northern section of the North Pacific Ocean trade route from April to December and the southern section of this route from December to April have ambient air temperatures within the ranges necessary for adequate cooling of these products (fig. 2 and table 3).

Several benefits would be derived by the shipper, carrier, receiver, and ultimately the consumer by transporting the appropriate products using only ambient air for cooling. By lessening competition for the refrigerated containers, more such containers would be available for shipping those products that require more critical temperature control. Shippers would have access to more equipment in which to ship their products overseas and carriers would also increase their revenues with an increase in total tonnage carried. In addition, some benefits in reduced transport costs might also result from substituting ventilated van containers for movement of some of the products now transported in refrigerated van containers since the ventilated containers should cost less to own and operate than the

TABLE 1.—*Recommended storage temperatures, approximate shelf life, and freezing points for commodity candidates shipped in ventilated van containers* [1]

Commodity	Recommended storage temperatures	Approximate length of storage	Highest freezing point
	° *F.*	*Weeks*	° *F.*
Grapefruit	50–60	4–6	30.0
Lemons	32–55	4–26	29.4
Limes	48–50	6–8	29.1
Olives, fresh	45–50	4–6	29.4
Casaba melons	45–50	4–6	30.1
Honeydew melons	45–50	3–4	30.3
Watermelons [2]	40–50	2–3	31.3
Sweet peppers	45–50	2–3	30.7
Potatoes, late crop	40–60	8–13	30.9
Pumpkins	50–55	8–13	30.5
Sweetpotatoes	55–60	17–26	29.7
Nuts [3]	50–70	4–130	----
Flower bulbs [3]	38–60	8–52	27.5–30.8

[1] U.S. Dept. Agr. Agr. Handb. 66, "The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks," 94 pp., 1968.

[2] Some varieties can be kept 2 to 3 months.

[3] Depending on variety; Agr. Handb. 66 should be consulted.

TABLE 2.—*Average range of air temperatures on North Atlantic Ocean* [1]

Month	U.S.A. to 60° W. longitude	60° W. longitude to 40° W. longitude	40° W. longitude to north Europe
	° *F.*	° *F.*	° *F.*
January	32–44	32–40	40–48
February	32–44	32–40	40–48
March	36–48	36–44	44–48
April	40–56	40–44	44–52
May	44–64	44–48	48–58
June	52–68	52–56	56–60
July	60–76	56–60	56–64
August	60–76	52–60	56–64
September	60–76	52–60	52–64
October	52–68	48–52	48–60
November	44–56	40–44	40–52
December	36–52	36–40	40–52

[1] Source: U.S. Weather Bur., "Climatological and Oceanographic Atlas for Mariners," v. I, "North Atlantic Ocean."

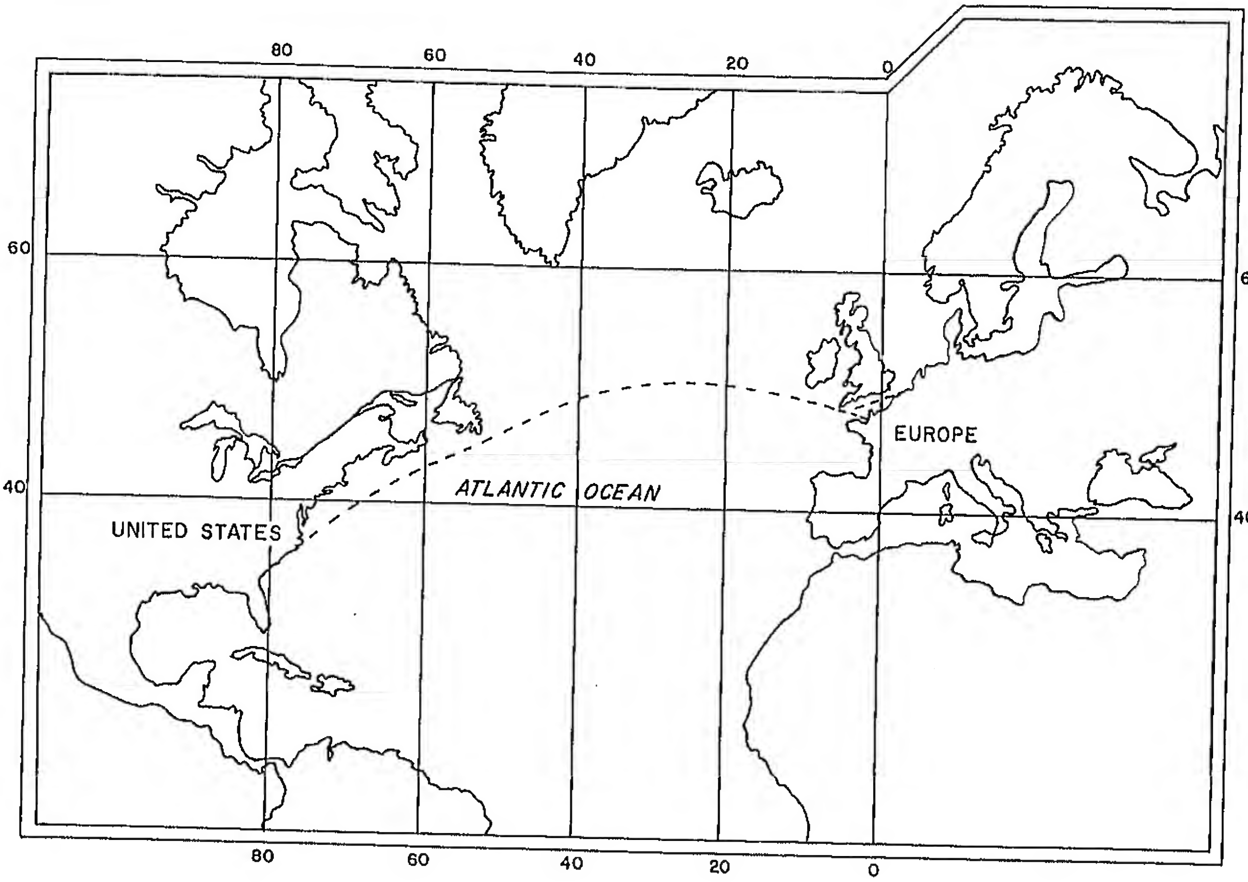


FIGURE 1.—Approximate North Atlantic trade route. Average air temperatures along this route in table 2.

refrigerated containers. Also, because of the greater interior cubic capacity and lower tare weight of the ventilated containers, the net weight of the cargo carried in them should be greater than that carried in the refrigerated containers.

In 1970, Hinds [1] reported the results of two experimental grapefruit shipments to Europe in ventilated van containers. Although the shipments arrived in good condition, problems during transport required further work on the design of the van container. One of the problems during transit was keeping water spray from entering the cargo compartment while allowing sufficient outside air to be drawn into the van for cooling the load. The only way to keep the water spray out of the cargo area was to close the vent doors on the front of the container. However, when this was done, the outside air could not be drawn into the van container to cool the cargo. Hinds concluded that a ventilation system that would allow sufficient outside air to enter the cargo compartment for cargo cooling while at the same time keeping out seawater was needed before shipments in ventilated van containers could become commercially feasible. He also suggested that an exhaust blower system to pull sufficient ambient air through the cargo was needed for effective product cooling.

This report presents the results of the research to develop a waterproof marine ventilation system for dry freight van containers and to assess the feasibility of its use. Its purpose also is to alert shippers, carriers, and equipment manufacturers that such equipment when properly used can successfully carry selected commodities that require moderately low temperatures.

[1] HINDS, R. H., JR., TRANSPORTING FRESH FRUITS AND VEGETABLES OVERSEAS. U.S. Dept. Agr. ARS 52-39, 34 pp., illus. 1970.

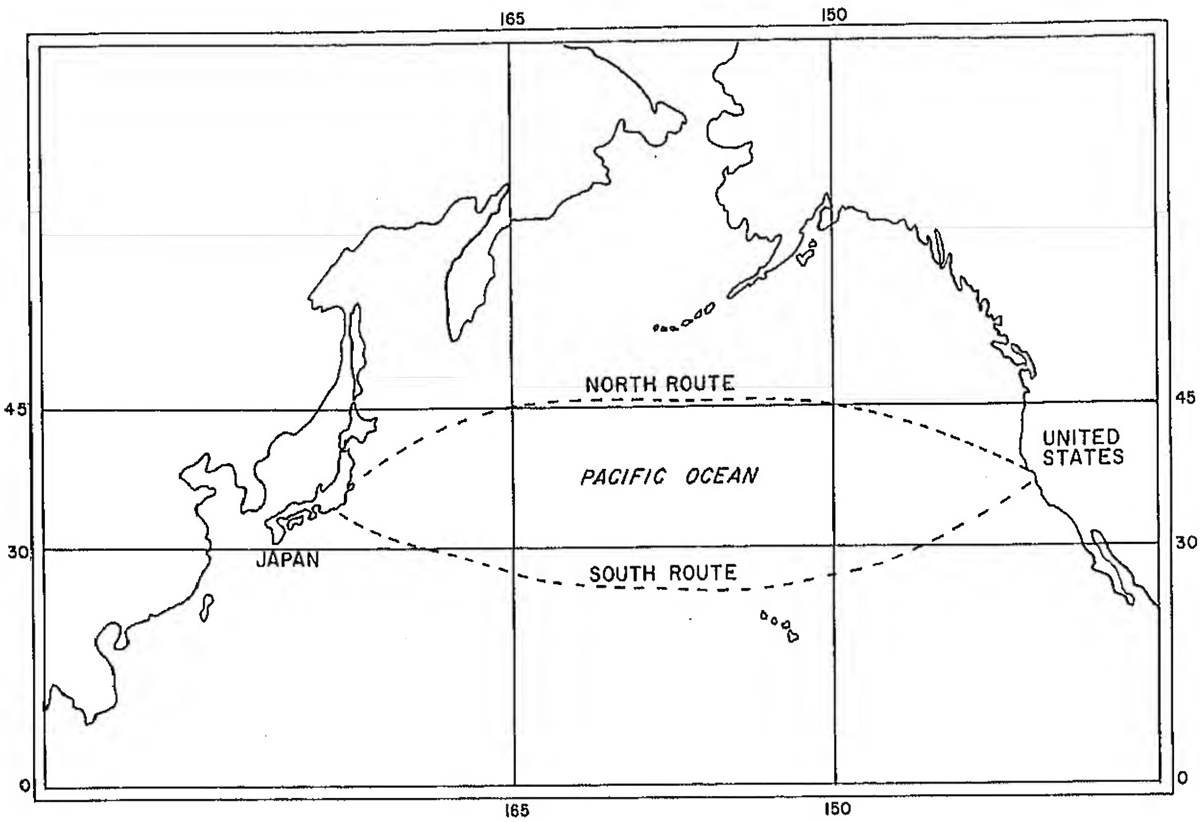


FIGURE 2.—Approximate North Pacific trade routes. Average air temperature along these routes in table 3.

TABLE 3.—*Average range of air temperatures on northern and southern sections of North Pacific Ocean* [1]

Month	Northern section			Southern section		
	U.S.A. to 150° W. longitude	150° W. to 165° W. longitude	165° W. longitude to Japan	U.S.A. to 150° W. longitude	150° W. to 165° W. longitude	165° W. longitude to Japan
	° F.	° F.	° F.	° F.	° F.	° F.
	46-52	36-46	36-44	52-64	60-64	44-64
	46-52	36-46	36-44	52-64	60-64	44-64
	46-52	36-46	36-48	52-64	64-68	48-68
	48-52	40-48	40-56	52-68	64-68	56-68
	50-56	42-50	42-60	56-72	72-76	54-76
	53-58	44-53	44-68	58-74	74-80	68-80
	56-58	52-58	52-76	58-74	74-82	76-82
	60-62	56-60	56-78	58-76	76-82	78-82
	58-62	58-62	58-72	60-76	76-82	74-82
	56-58	52-58	52-64	58-74	74-80	66-80
	50-56	44-50	44-56	56-72	72-76	58-76
	48-52	40-48	40-52	54-68	68-72	52-72

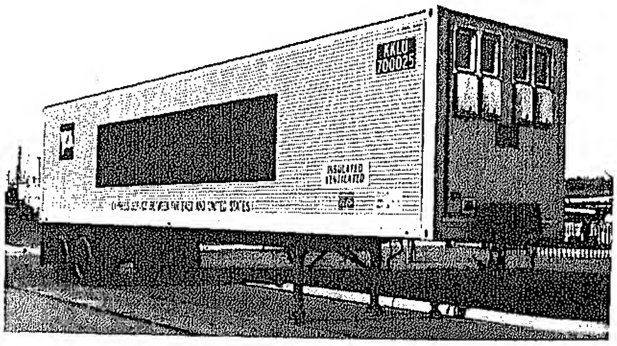
…r Bur., "Climatological and Oceanographic Atlas for Mariners," v. II, "North Pacific Ocean"; and …apan), "Temperature Route Study," Feb. 1971.

EQUIPMENT AND SYSTEMS EVALUATED

Van Container

A ventilated dry freight van container with outside measurements of 40 feet long, 8 feet wide, and 8 feet high, meeting the International Standards Organization size specifications, was used to develop and test the marine plug and and ventilation system. The van container was equipped with four vents at the front and four vents at the rear (fig. 3). The vents measured 9 inches wide by 15.5 inches high. Each vent was backed with a TIR[2] grid of pierced aluminum alloy (fig. 4).

The van container was lightly insulated with 2 inches of foamed-in-place polyurethane in the sidewalls, floor, and ceiling. The interior surfaces of the container were flush, with no ribs on the sidewalls nor racks on the floor. Interior measurements were 39 feet 2 inches from the front bulkhead to the rear doors, 7 feet 6 inches between the sidewalls, and 7 feet 8 inches from the floor to the ceiling. The stationary forward bulkhead was 4 inches in from the front end wall and had an approved TIR perforated grid across the bottom width. The top of the bulkhead had a sideways V-shaped baffle air deflector 1½ inches down from the ceiling and was covered with a TIR grid (see fig. 4). The purpose of the baffle was to deflect about a fifth of the incoming air over the top of the load and force the remainder into the space behind the bulkhead so it could enter the cargo area near the floor of the container. To test this original configuration, a 15-inch-wide squirrel-cage-type blower powered by a 1-hp. motor was installed in the lower left rear vent to pull air through the van container.



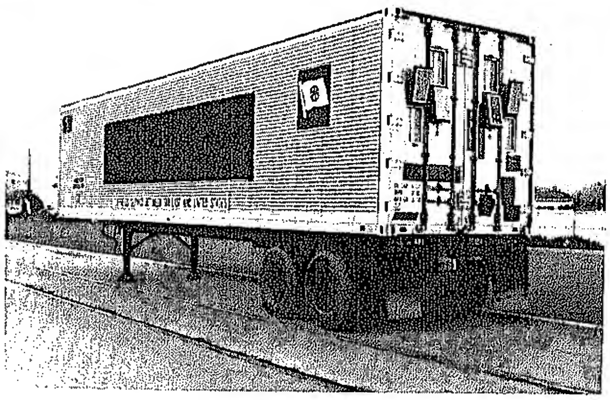


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FIGURE 3.—Ventilated van container, showing front (top) and rear (bottom) vents.

The air velocity in the van container was measured with probes of a hot wire anemometer. These measurements showed that the distribution of the circulating air was almost the direct opposite of the distribution required for adequate load cooling. About 30 percent of the air was directed into the cargo area through the opening at the bottom of the bulkhead and 70 percent was directed over the top of the load. The path of least resistance to the moving air was through the top opening of the bulkhead. The movement of air over the top of the load is unsatisfactory for product cooling since this path allows it to contact only a small part of

[2] TIR is the abbreviation for the French "Transports Internationale Routier," or International Road Transport. It refers to the so-called TIR Convention, which fixes the conditions for the free movement of van containers between signatory countries. The Convention has been ratified by most of the trading nations of the world, including the United States. Under the terms of the Convention, all signatory countries will allow loaded and empty van containers meeting the TIR specifications and accompanied by an appropriate TIR carnet (a shipping document guaranteeing the payment of all customs duties) to move freely through the ports of entry to interior destinations and to pass through one country to a destination in another country without the usual border delay for customs inspections. TIR grids or screens are required on van container ventilation openings to prevent rats and other rodents from entering the container and being carried from one country to another. They also prevent theft of cargo from, and smuggling of goods in, these unsealed openings.

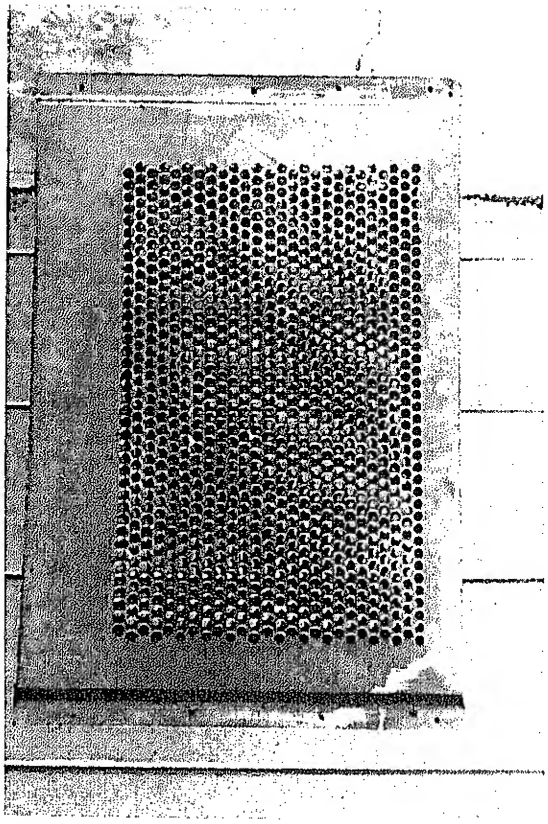

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FIGURE 4.—Pierced aluminum TIR grid used to protect front and rear vents of ventilated van container.

the load. To get the most benefit from the cooling effect of incoming air, all or most of the air must be forced to go through the load. To redirect the air through the load, the top opening of the bulkhead was covered with aluminum tape, forcing all the air to enter the cargo compartment at the bottom opening of the bulkhead. Measurements were again made of air velocity to determine whether adequate amounts of air were entering the cargo area at the bottom of the bulkhead. These measurements revealed that this configuration did not allow sufficient air to enter the cargo area for adequate cooling of the load.

Each of the front end vents covered by the TIR-approved pierced aluminum grid measured 9 inches wide by 15.5 inches high or 139.5 square inches. The area of the openings in the grid totaled 65 square inches, or only 46 percent of the surface area of the vents. Therefore the remaining 54 percent of the area effectively blocked air movement through the grid. The forward surface of the bulkhead was 4 inches in from the front end wall of the container. The space between the bulkhead and the front end wall was not sufficient to allow enough air to reach the cargo area of the van container after entering through the vents.

To increase the volume and the velocity of the air flowing into the cargo area of the container, the following modifications were made:

(1) The TIR pierced aluminum grid was removed from the front end vents and replaced with TIR-approved mesh screen with an open area equal to 56 percent of the surface area of the vent (fig. 5).

(2) The bulkhead was moved 2 inches farther from the front end wall so that there was a 6-inch-deep space between the front end wall forward surface and the bulkhead. Moving the bulkhead 2 inches toward the rear reduced the length of the cargo area to 39 feet.

(3) The sideways V-shaped air deflector was removed and the height of the bulkhead was extended to the ceiling of the container.

These modifications were included in subsequent tests made with the van container and the same configuration was maintained when

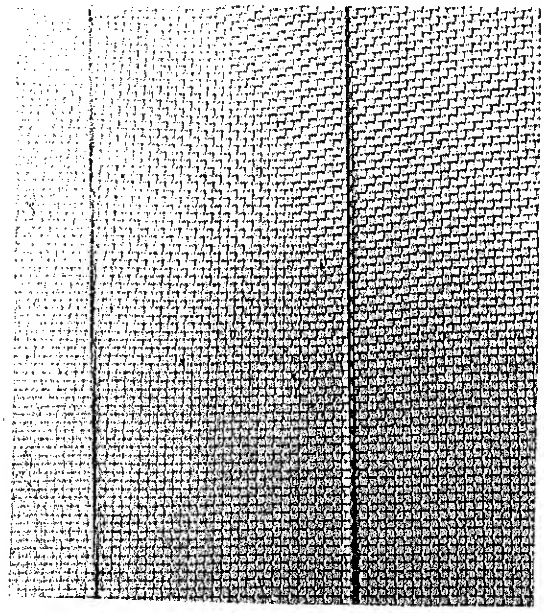

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FIGURE 5.—TIR mesh screen used to replace pierced aluminum TIR grid.

marine plug "C" was built into the interior of the van except the cargo space was reduced to 38 feet 6 inches.

Types of Marine Plugs Tested

Marine Plug "A"

This plug consisted of four inverted L-shaped ducts attached to the van container by means of a picture frame mounting (fig. 6). The ducts and the picture frame mounting were constructed of 18-gage galvanized sheet steel.

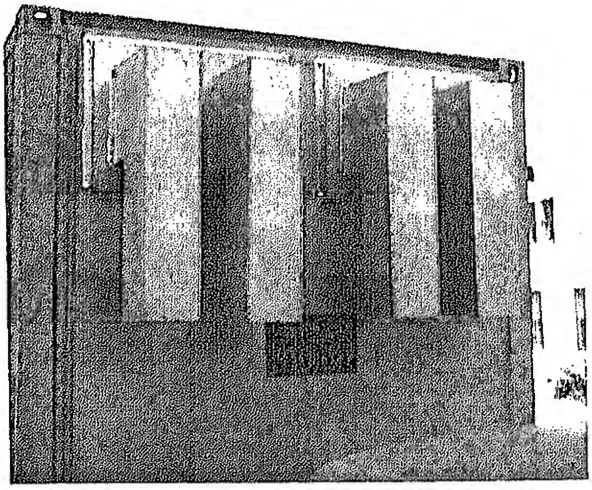

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FIGURE 6.—Marine plug "A" mounted on front of van container.

Marine Plug "B"

This unit consisted of four individually mounted plugs that fitted into each front end vent (fig. 7). Each plug contained 11 baffles opposite each other to allow the outside air to enter while at the same time deflecting the water to keep it from entering the vent (fig. 8).

Marine Plug "C"

This installation consisted of one large duct covering the entire front of the van container (fig. 9). The opening was covered with TIR-approved mesh screen. A baffle plate was installed behind the screen to deflect downward the air and water spray as they entered the vent. The outside bottom of the plug was tapered inward toward the front of the container to provide a water-gathering chamber. The bottom of the plug had two ½- by 4-inch drain holes at the corners and five ½-inch-diameter drain holes evenly spaced between the larger drains to permit the accumulated water to drain to the outside. (Fig. 10.)

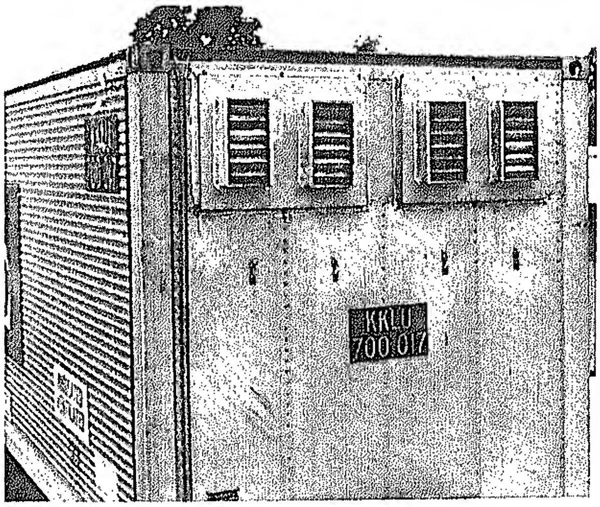

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FIGURE 7.—Marine plug "B" mounted in front vents of van container.

After necessary modifications were made to the van container, a wooden prototype of marine plug "C" was constructed and installed across the ventilation openings on the front of the van container. Tests of this installation were made to determine the best spacing of the baffle plate behind the screen. When a 2-inch space from the front of the plug to the baffle proved to be the optimum, another marine plug "C" was constructed of 24-gage galvanized sheet steel and installed.

Marine Plug "C" Built Into Interior of Van

The results of the first shipping tests with the ventilated van container equipped with the external marine plug encouraged the researchers to continue work with the system to further refine it. The van container again was modified to make the marine plug an integral part of the interior of the container (fig. 11).

The bulkhead was moved back toward the rear of the container another 6 inches, reducing the interior length of the cargo compartment to

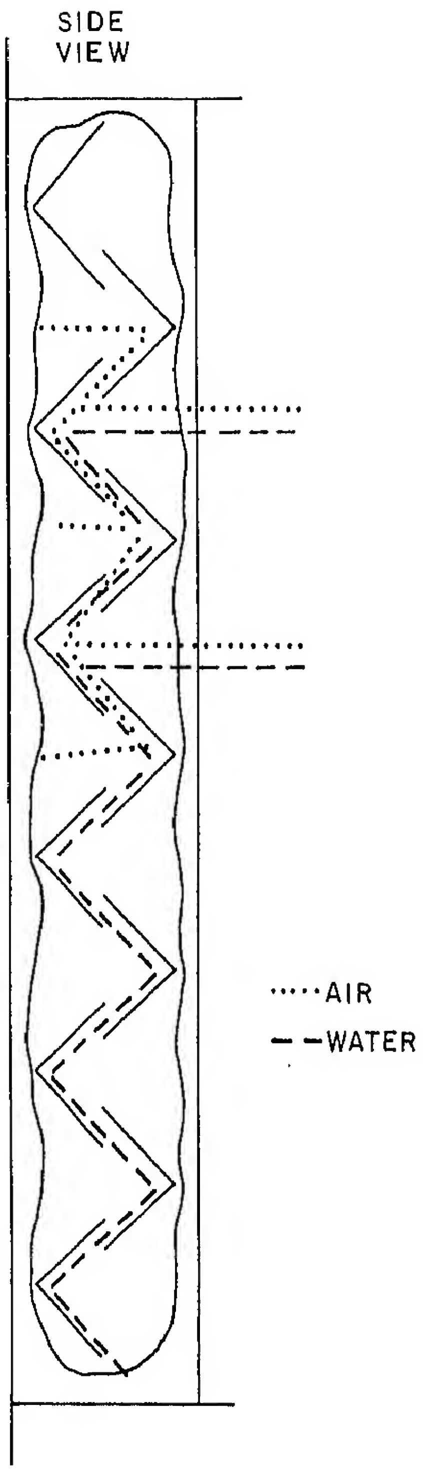

FIGURE 8.—Cut-away view of marine plug "B," showing flow of air and water.

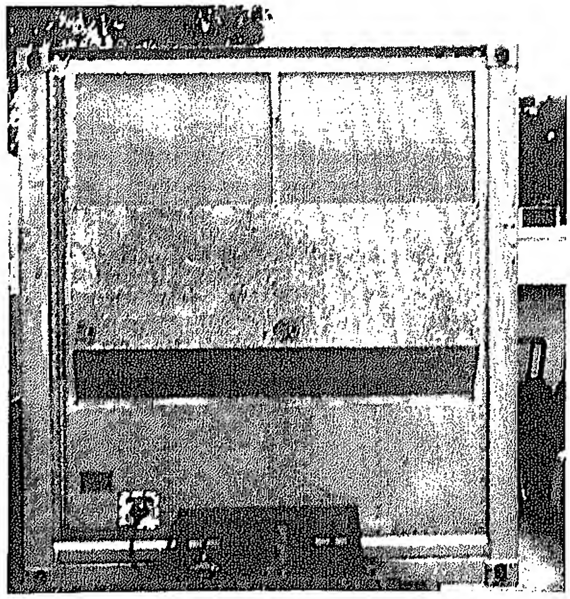

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FIGURE 9.—Marine plug "C" mounted on front of van container.

38 feet 6 inches. The TIR mesh screen was installed in each of the front end vents. An aluminum baffle extending downward from the ceiling was installed 2 inches behind the screen. This baffle coincided with the baffle on marine plug "C" and deflected the incoming air and water downward. A 6-foot-high aluminum shield was installed from the floor upward, 4 inches behind the aluminum baffle to form a gutter to lead the deflected water to the container drains. In addition to the existing drain holes in the floor at the front of the container, two more 1½-inch-diameter drain holes were cut into the front floor adjacent to the existing drains to further increase drainage capacity. A rounded air deflector of aluminum alloy sheet was installed between the front of the bulkhead and the back of the baffle.

A thermostat was placed on the back side of the baffle and a 6-inch modulating damper was installed between the front of the bulkhead and the aluminum shield. The thermostat controlled the damper, which cut off entrance of outside air into the container when the air temperature fell below the thermostat setting and prevented freezing or chilling damage to the product. A 220-volt waterproof electrical receptacle (fig. 12) was installed on the outside

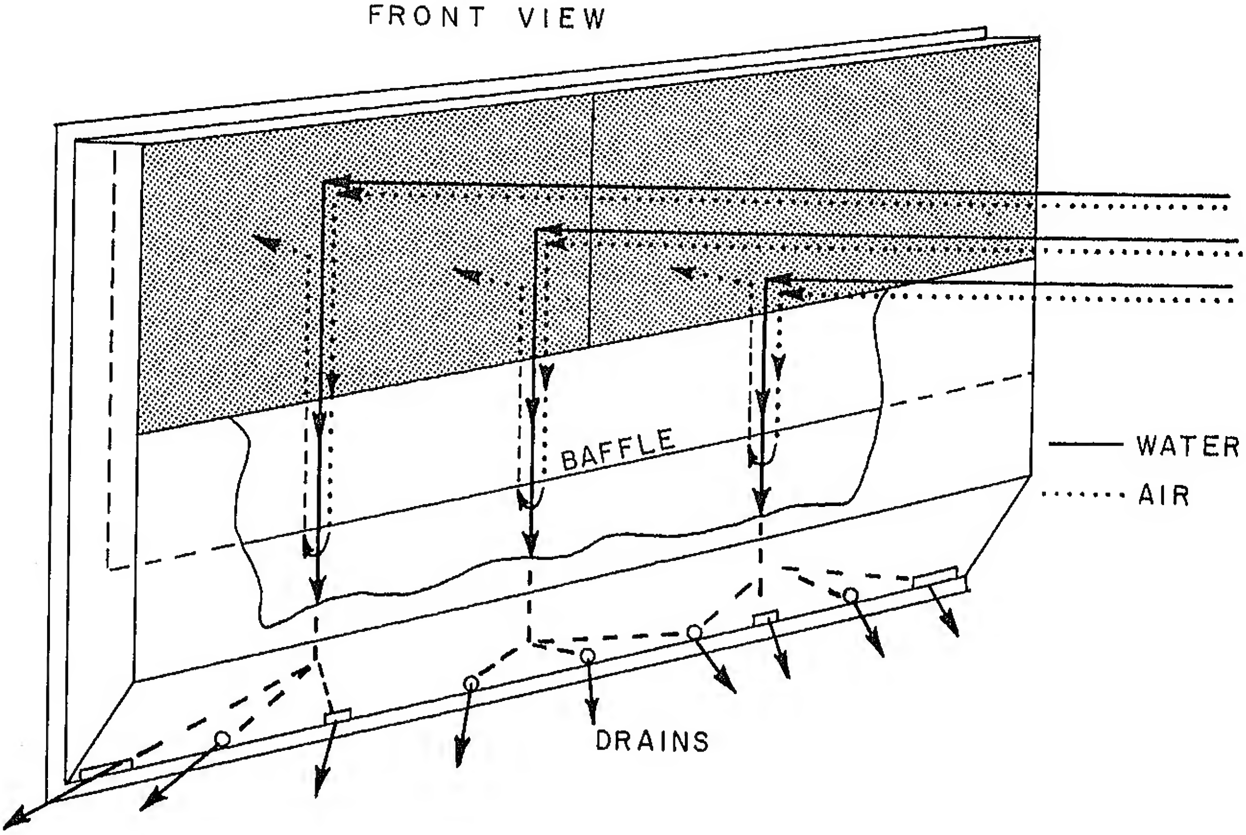

FIGURE 10.—Cutaway view of marine plug "C," depicting flow of air and water.

of the front of the van container to permit use of the ship's electrical power needed to operate the exhaust blowers and the air damper system. The electrical line from the external receptacle was connected to the damper and the rear blowers.

When the ambient or outside air temperature falls below the thermostat setting, a relay is opened that causes the damper to close and the exhaust blowers to stop operating. Conversely, when the air temperature goes above the thermostat setting, the relay closes the switch the damper is opened, and the blowers begi operating. The rear of the van container re mained as it was with the blowers installed the outside of the two rear vents (see fig.

Exhaust Blowers

The air exhaust system consisted of centrifugal discharge fans or squirrel-cage blowers with forward curved blades and single inlet. They were mounted for down-blast discharge. The supply inlet was used as cargo space exhaust. The blowers were Dayton model 2C989 with 15- by 6-inch wheel, ¾-inch shaft, 15⅞-inch-diameter inlet, and 15⅞-by-8¼-inch outlet. Overall they were 25 by 12½ by 22½ inches. (Fig. 13.)

Exhaust Blower Motor

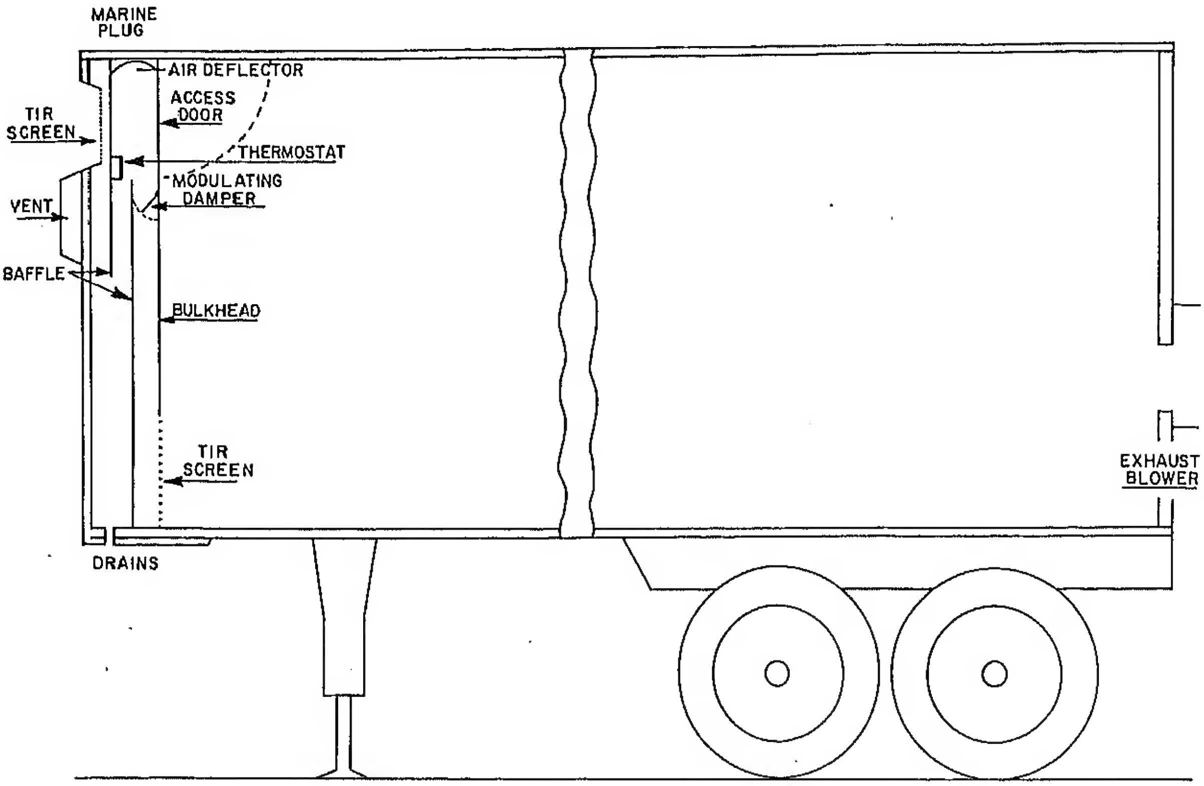

FIGURE 11.—Ventilated van container modified to incorporate waterproof marine plug as an integral part of the van container.

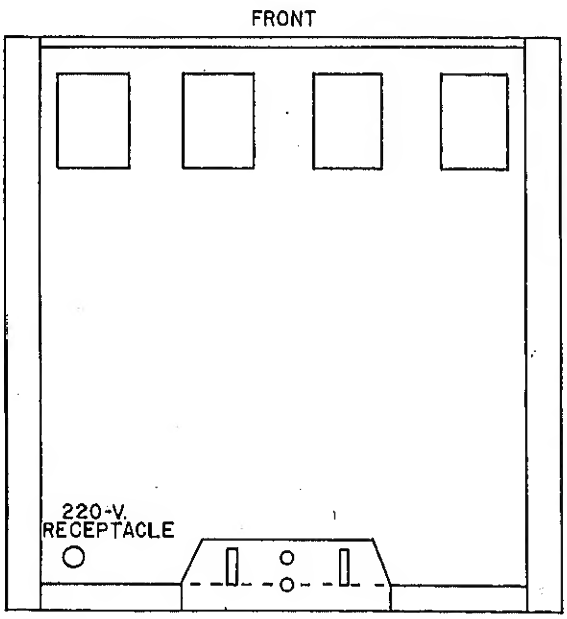

FIGURE 12.—220-volt marine-type waterproof receptacle installed on front of van container.

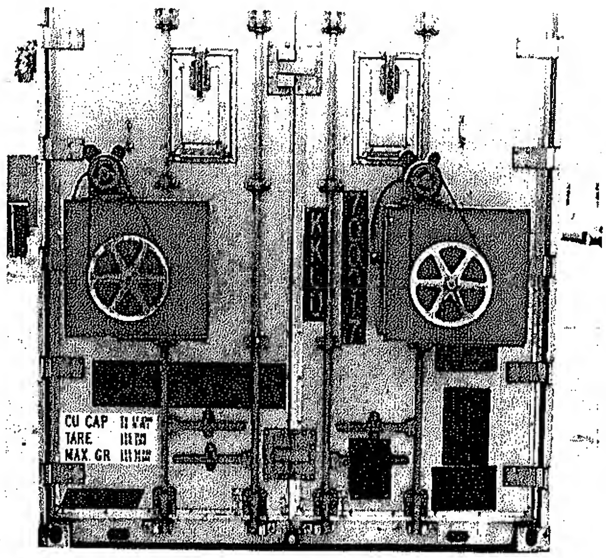

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FIGURE 13.—Two 15-inch-wide squirrel-cage-type exhaust blowers powered by two 1½-hp. electric motors mounted on two lower rear vents to pull air through load.

PROCEDURES

Preliminary Testing

Twelve stationary tests and eight moving tests by highway transport were made to evaluate the three types of waterproof plugs used in this research. The stationary tests were made at the Orlando, Fla., field station and at citrus packinghouses in central Florida. The moving tests on the highways were conducted in and around Orlando.

Air velocity measurements were taken with an Anemotherm anemometer (hot wire-type). Temperatures of the air and the fruit were measured by thermocouple leads placed in fruit pulp in predetermined strategic positions in the load and in the air spaces surrounding the loads. Temperature readings were transcribed on a Honeywell Electronic Recorder and portable potentiometer. Each type of hatch plug was tested to determine whether it would allow sufficient air into the container to cool a load and whether it would keep water out of the cargo compartment. Type "C" marine plug was found to be the only one that would perform satisfactorily from both standpoints and this design subsequently was used in overseas shipping tests for further evaluation in the particular operating environment for which it was intended. Later the type "C" marine plug configuration was built into the interior of the van and tested further in overseas shipments.

Grapefruit Shipping Tests

The first shipping test to an overseas destination was made with the ventilated van container with marine plug "C" mounted on the front end. Two 15-inch-wide squirrel-cage-type exhaust blowers, powered by two 1½-hp. electric motors, were mounted on the two lower rear door vents to pull the ambient outside air through the van. The van container was loaded with 975 [3] boxes of grapefruit in the USDA's recommended modified bonded-block pattern.[4] These ⅘-bushel boxes were of corrugated fiberboard. The top layer of the load was covered with sheets of corrugated fiberboard to prevent incoming air from leaking upward from ventilation channels in the body of the load. Thus the incoming cool air from outside the van entering the cargo area at the bottom of the bulkhead was forced to pass through the entire length of the load before being exhausted through the two lower rear door vents by the air blowers. To stabilize and prevent rearward shift of the load, aluminum alloy load-restraining bars were locked in place against the rear stack of the load (figs. 14 and 15).

Three conventional 40-foot-long refrigerated van containers used as controls were each loaded with 900 ⅘-bushel boxes of grapefruit in the modified bonded-block pattern. The loads in the refrigerated containers were braced with

[3] Container could have been loaded with 1,000 boxes and still be within applicable highway weight limits. Decision was made to load 975 boxes to remain under legal highway load limits and to provide space at the rear for researcher to work.

[4] HINDS, R. H., JR., and ROBERTSON, J. K. A BETTER PATTERN FOR TRAILER SHIPMENTS OF CITRUS FRUITS. U.S. Dept. Agr. Mktg. Res. Rpt. 715, 9 pp., illus. 1965.

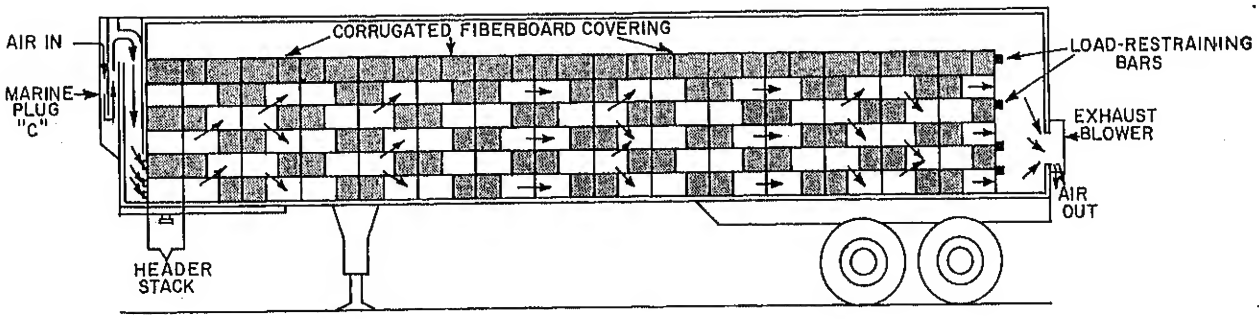

FIGURE 14.—Cross-sectional view of ventilated van container with grapefruit load, showing marine plug "C" installed, bonded-block pattern load, air direction through load, corrugated fiberboard covering, load-restraining bars, and exhaust blower.

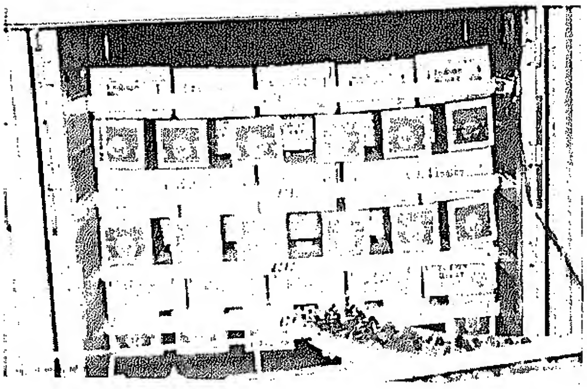

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FIGURE 15.—Rear of grapefruit load in ventilated van container at shipping point, showing aluminum alloy load-restraining bars.

wooden gates at the rear stack (fig. 16). All thermostats in the mechanical refrigeration units on these van containers were set at 60° F. The three loaded refrigerated van containers were transported via piggyback from Vero Beach, Fla., to the port of Norfolk, Va. The ventilated van container was transported over the highway from Vero Beach to the same point.

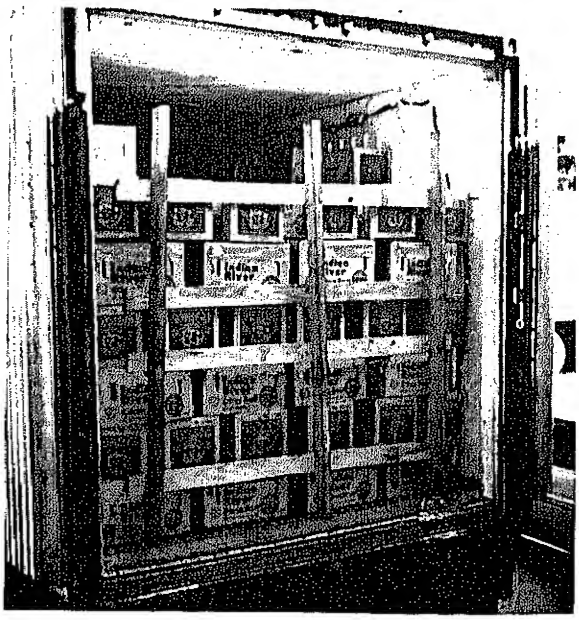

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FIGURE 16.—Refrigerated van container at shipping point with grapefruit boxes loaded in USDA's recommended bonded-block pattern. Note wooden endgate in place.

Thermocouple leads were put in all the loads to enable the monitoring of both air and fruit pulp temperatures during transit (fig. 17). All four containers were loaded aboard the same ship and carried to the same destination. USDA researchers accompanied the experimental loads, monitoring air and fruit temperatures in all four van containers and measuring air velocity in the ventilated van container during the voyage. The researchers also collected data on handling times and costs at loading, during transit, and at destination.

Watermelon Shipping Tests

Three van container shipments of watermelons were made from Florida to London, England, in May and June 1971.[5] One of the shipments was in the modified ventilated van container. The other two shipments made 2 weeks later were in conventional 40-foot refrigerated van containers. The ventilated load consisted of 560 fiberboard boxes of melons weighing approximately 70 pounds each. The two refrigerated containers were each loaded with 513 boxes. Load weights ranged from 16.5 to 20 tons per van container. Transit time from loading to unloading ranged from 14 to 17 days. Varieties of watermelons shipped were F-1 Hybrid, Charleston Grey, Crimson Sweet, and Jubilee. The melons weighed from 12 to 25 pounds.

All melons were packed in two types of corrugated fiberboard boxes—regular slotted double-wall corrugated fiberboard boxes in the first shipment and part-telescope single-wall corrugated fiberboard boxes in the other two shipments. The boxes of melons in the ventilated van and one refrigerated van were palletized on expendable wooden pallets; in the second refrigerated van container the boxes were hand stacked.

Ryan recording thermographs were placed in each shipment to record air temperatures. Pulp temperatures of the melons at selected points

[5] For additional information on shipping watermelons to England, see U.S. Dept. Agr. ARS 52-71, "Feasibility of Exporting Watermelons to England," by Lawrence A. Risse and Russell H. Hinds, Jr., 1972.

throughout the load were taken at the time of loading and unloading with stick-type thermometers and at the embarkation point for the ventilated van.

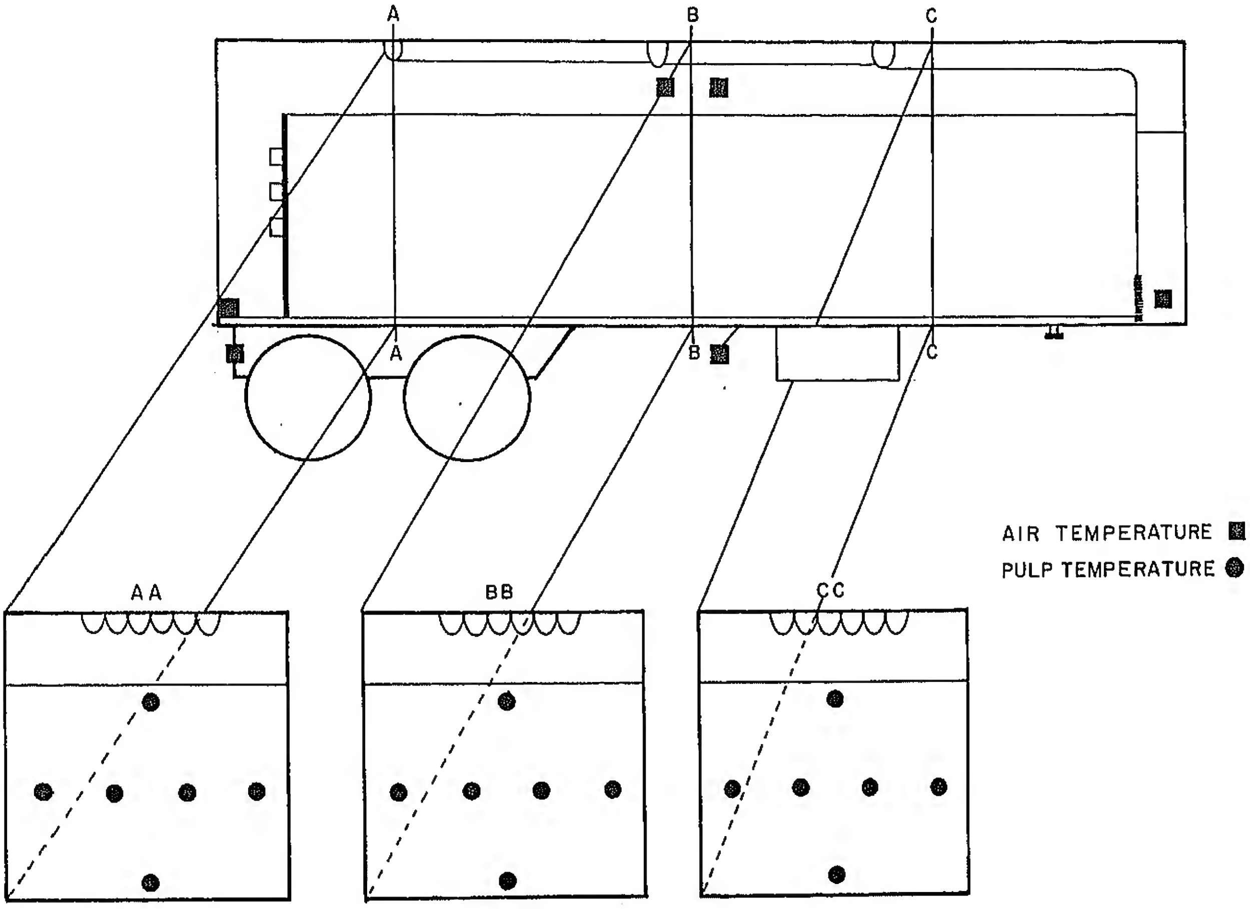


FIGURE 17.—Thermocouple locations within van containers to monitor fruit pulp and air temperatures in grapefruit shipments.

RESULTS

Preliminary Testing

The type of tests and the results with the original ventilated van without changes and with the three different designs of marine plugs are shown in table 4. Marine plug "A" failed to meet the criteria of allowing sufficient outside air to enter the cargo area of the container while keeping out the water that was sprayed on the plug to simulate ocean spray. The inverted L-design vent plug seriously restricted the amount of air entering the cargo compartment of the container. Since this design did not allow sufficient air to enter the container, it was eliminated from further consideration.

The compactness of marine plug "B" encouraged researchers to extend its testing to see whether it would meet the design criteria. However, it also failed for the same reason as plug "A" and was eliminated from further testing.

Results of stationary and moving tests with marine plug "C" indicated that sufficient air would enter the cargo compartment through this design to provide ambient air cooling of the cargo. Further tests were made to determine whether this design would prevent water from entering the cargo compartment. When

TABLE 4.—*Preliminary evaluations of ventilated van container with and without marine plugs and forced air ventilation systems*

Test No.	Condition	Marine plug	Van container configuration	Blower	Motor [1]	Load	Air readings taken at—	Average air velocity
				Number	*Hp.*			*F.p.m.*
1	Stationary	None	Original with front vents open.	1	1	Empty	Top of bulkhead.	200
							Bottom of bulkhead.	62.5
2	do	do	Top of bulkhead blocked.	1	1	do	Bottom of bulkhead.	107
3	do	do	do	1	[2] 1½	do	do	96
4	Moving on highway 25-30 m.p.h.	do	Front vents open, 1 rear vent open.	0	0	do	do	95
5	Moving on highway 40-50 m.p.h.	do	do	0	0	do	do	116
6	Stationary	A [3]	do	1	1½	do	do	89
7	Moving 25-30 m.p.h.	A	do	1	1½	do	do	[4] 0
8	Moving 40-50 m.p.h.	A	do	1	1½	do	do	45
9	Stationary	B [3]	do	1	1½	do	do	54
10	Moving 25-30 m.p.h.	B	do	1	1½	do	do	40
11	Moving 40-50 m.p.h.	B	do	1	1½	do	do	65
12	Stationary	B	do	1	1½	954 ⅘-bushel boxes of grapefruit.	Rear air channels of load.	0
13	do	B	Front vents open, 2 rear vents open.	2	1½	Empty	Bottom of bulkhead.	76
14	do	None	Modified (see text); front vents open, 2 rear vents open.	2	1½	do	do	179
15	do	do	do	2	1½	do	do	207
16	do	do	do	2	1½	990 ⅘-bushel boxes of grapefruit.	Rear air channels of load.	[5] 20-85
17	do	C [3]	Front vents open, 2 rear vents open.	2	1½	Empty	Bottom of bulkhead.	166
18	Moving 20 m.p.h.	C	do	2	1½	do	do	98
19	Moving 50 m.p.h.	C	do	2	1½	do	do	169
20	Stationary	C	do	2	1½	954 ⅘-bushel boxes of grapefruit.	Rear air channels of load.	[6] 35-65

[1] For tests 1-3 and 6-12, 1 motor was used for each test; for tests 13-20, 2 motors were used for each test.
[2] Subsequent tests were made with 2 blowers with larger motors.
[3] For description of marine plug, see text.
[4] During highway transport, the slipstream of moving air along the sides of the tractor and container on chassis combination created a low pressure area between the rear of the cab and the front of the container and pulled the air out of the container's interior, creating a reverse airflow in the container.
[5] Sheets of corrugated fiberboard covering the top layer of the load in the forward quarter length of the container prevented the incoming air from moving over the top of the load. Air velocity over top ranged 60-75 f.p.m.
[6] Sheets of corrugated fiberboard covering the entire load to prevent air from coming over the top. Air velocity over top ranged 15-25 f.p.m. Sufficient air coming through the load to conduct an overseas test.

ll tests confirmed that marine plug "C," used ı conjunction with two 15-inch exhaust air lowers powered by two 1½-hp. motors to pull ir through the container, met the criteria esıblished for a suitable ventilation system, a ›mmercial overseas test shipment was made.

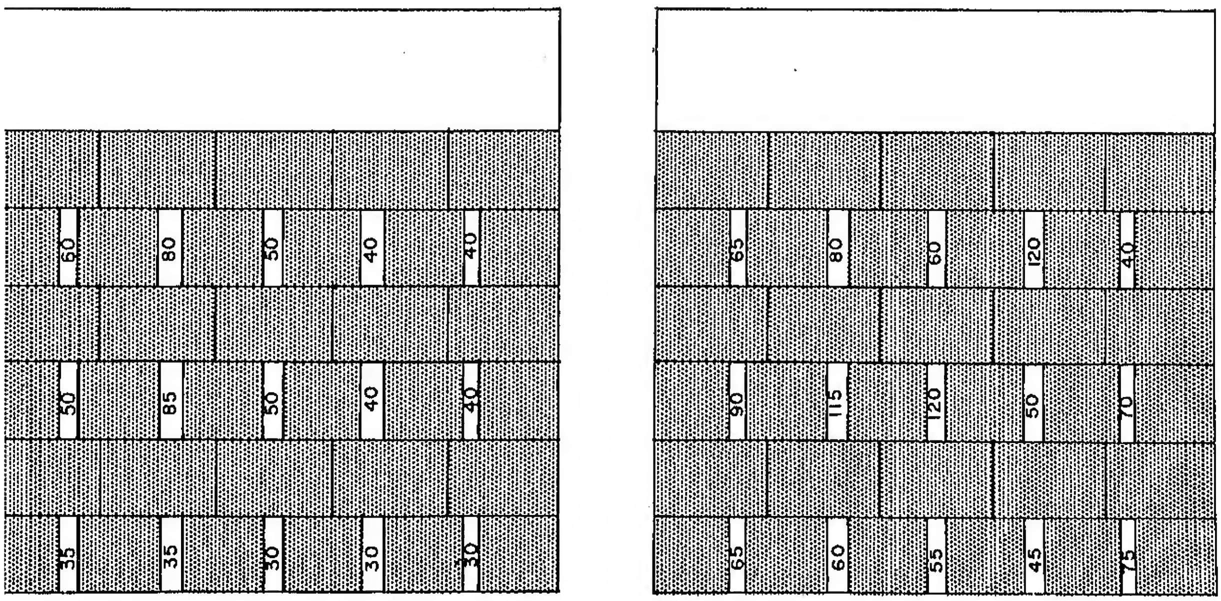
Grapefruit Shipping Tests

The average pulp temperature of the grape-ruit in the ventilated van at loading was 83° F. y the fifth day after loading, the average ›mperature had dropped to 63° and by the ›nth day to 60° (table 5). From this point ıtil the conclusion of the test on the 15th ıy, the temperature ranged between 54° and l°. By the fifth day the spread between the gh and low product temperatures was 4°, dicating that all the air channels through the ad had remained open and that ambient air sufficient quantity was reaching the boxes the load. The variations in the temperatures the load paralleled the rise and fall of the nbient temperatures.

Air velocity measurements in the load were ken at sea during a calm period and when e wind velocity was as high as 40 m.p.h. These observations showed that at such high wind velocities the exhaust blowers were not needed to pull air through the load (fig. 18).

The load pattern in the ventilated van was found to be intact with no shifting or damage to the cargo when the load was inspected at destination (fig. 19). The cartons were dry and very little crushing of boxes due to overhead weight was noted. Pulp temperatures averaged 54° F. There was no rind pitting or fruit decay reported by the French agricultural inspector.

The average pulp temperature of the grapefruit in the three refrigerated van containers at loading was 81° F. (table 6). By the fifth day after loading the average temperature had dropped to 59°. From the fifth to the 14th day the average pulp temperature fluctuated between 59° and 62°. (For detailed temperature data, see table 7 in appendix.) At the conclusion of the test on the 15th day the average fruit pulp temperature was 57°. After the fifth day the largest spread between the high and low product temperature in all load locations monitored was 7°, indicating that the air temperature within the container fluctuated considerably.



GURE 18.—Air velocities (f.p.m.) taken at sea in channel locations at rear of grapefruit load: *Left*, wind velocity 40 m.p.h., air entering van container 1,300 f.p.m., exhaust blower OFF; *right*, wind calm, air entering van container 700 f.p.m., exhaust blower ON.

TABLE 5.—*Average product and ambient air temperatures of grapefruit shipment in ventilated van container by location in load, Florida to France, October 1970* [1]

Days after loading	Product temperature					Ambient air temperature
	Top	Bottom	Center	Right wall	Left wall	
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Start	83	83	83	84	83	80
5th	65	61	62	63	62	57
6th	65	65	64	63	62	60
7th	67	67	66	66	66	65
8th	64	63	63	64	64	63
9th	63	61	60	61	60	47
10th	59	56	58	56	58	50
11th	59	57	59	61	58	53
12th	60	58	59	59	58	56
13th	60	60	60	61	60	56
14th	60	60	60	60	60	55
15th	54	54	54	55	55	52

[1] Each of the top, bottom, right wall, and left wall readings is an average of 3 locations; center is average of 6 locations in center of load. (See fig. 15.)

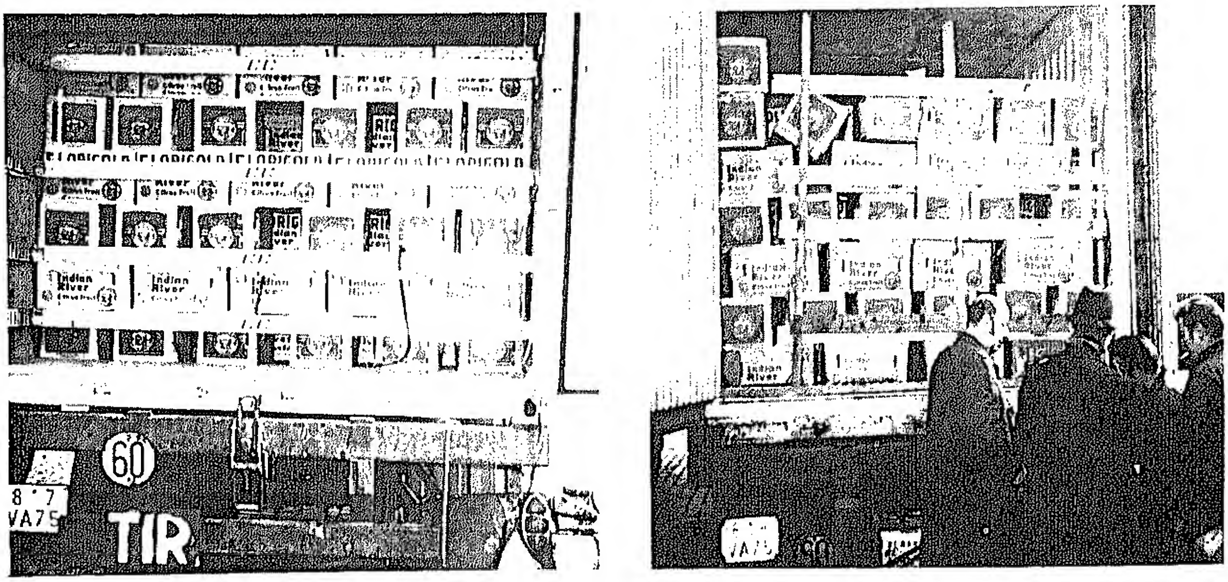
TABLE 6.—*Average product and ambient air temperatures of grapefruit shipments in 3 refrigerated van containers by location in load, Florida to France, October 1970* [1]

Days after loading	Product temperature					Ambient air temperature	Average thermostat setting
	Top	Bottom	Center	Right wall	Left wall		
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Start	81	79	81	81	81	80	60
5th	59	60	60	59	59	57	60
6th	61	60	60	60	60	60	60
7th	61	60	60	61	60	65	60
8th	61	62	62	61	60	63	60
9th	62	62	62	61	61	47	[2] 59
10th	60	61	60	60	60	50	59
11th	60	61	60	60	60	53	59
12th	62	62	62	62	62	56	59
13th	62	63	63	62	63	56	[2] 58
14th	59	61	60	60	60	55	[2] 54
15th	56	57	57	57	57	56	54

[1] Each of the top, bottom, right wall, and left wall readings is an average of 3 locations; center is average of 6 locations in center of load. (See fig. 16.)

[2] Thermostat reset.

During transit, USDA researchers changed thermostat settings on each refrigerated van container at least once to prevent chilling or overheating the fruit (table 7). Upon inspecting the loads at destination, most of the boxes were found to be wet and 30 to 50 boxes on the bottom layer of each van container were partly crushed by the overhead weight of boxes in the upper layer of the load (fig. 19). However, the fruit was not damaged; it was firm and of good color.



PN-3246, PN-3247

FIGURE 19.—Arrival condition of Florida grapefruit shipment in ventilated (left) and refrigerated (right) van containers, Le Havre, France, after 15 days in transit.

Watermelon Shipping Tests

At the time of loading the modified ventilated van container, the outside air was near 100° F. and melon pulp ranged from 88° to 92°. After loading, the shipment was transported over the highway to Norfolk, Va., for loading aboard a containership bound for England. The melon pulp averaged 90° at loading and ranged from 56° to 62° upon arrival in London (fig. 20). The changes in melon temperature paralleled closely the trend in average temperatures of the outside air entering the van container.

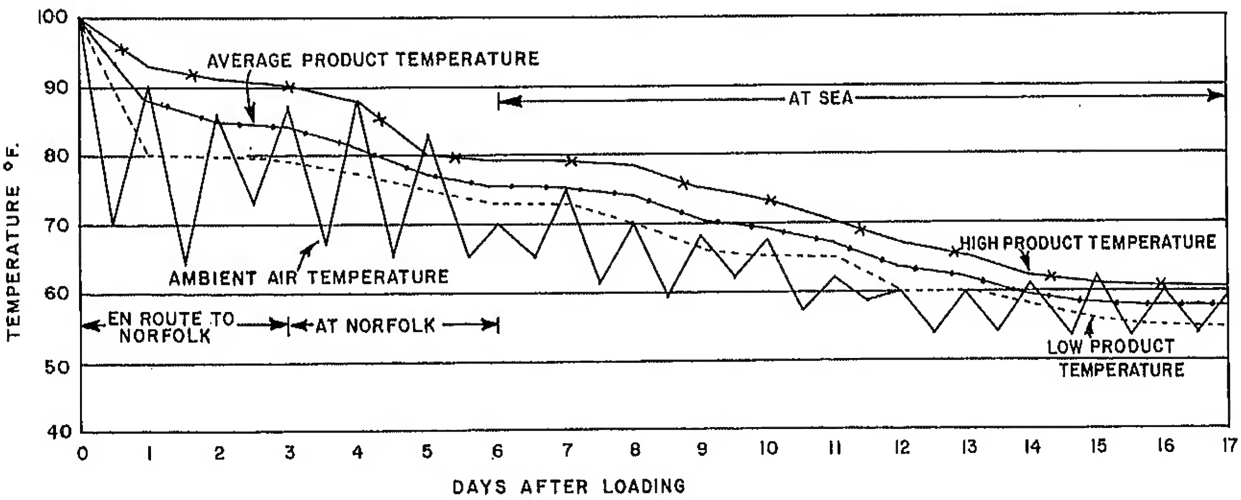


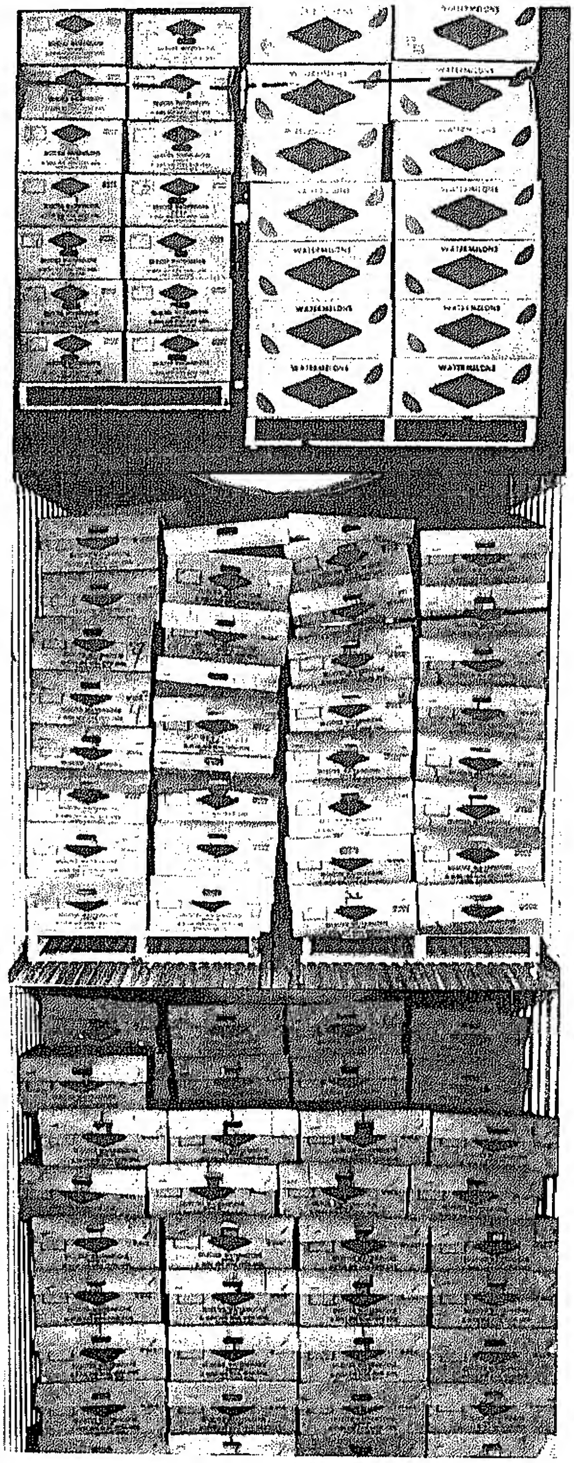
FIGURE 20.—Product and ambient air temperatures of watermelon shipment in ventilated van container, Florida to England, 1971.

The arrival condition of the palletized load of watermelons in the ventilated van container was excellent (fig. 21). Less than 2 percent of the melons were found to be damaged upon arrival at the retail level. The bracing at the rear of the load and between the pallets was intact. The corrugated fiberboard boxes used in this load were of double-wall construction and held up well in transit with some slight bulging of the lower layer boxes because of overhead weight. There was no damage associated with the transportation of the melons.

The receiver was pleased with the condition of the melons and sales were above expectations, resulting in an additional order of two van container loads. Since no other satisfactory ventilated vans were available, two refrigerated van containers were used.

The two refrigerated van containers were loaded 2 weeks later. Watermelon pulp at the time of loading ranged from 85° to 93° F. with an average of 89°. Thermostats on the refrigeration units were set at 60°. The temperature of air surrounding the melons in the middle of the load in both refrigerated containers reached 70° within 4 days after loading. Ambient air temperatures at the time of unloading ranged from 62° to 68° with an average of 65°.

Melon pulp in both refrigerated loads ranged from 62° to 68° F. on arrival. The arrival condition of both refrigerated watermelon shipments (one palletized and the other hand stacked) was not nearly so satisfactory as the load in the ventilated van container (fig. 21). However, this was not so much due to the van containers as to other variables. The single-wall boxes used in these two loads did not perform as well as the double-wall boxes in the ventilated van container. The boxes in the middle and lower layers of the loads showed a considerable amount of bulging and crushing from the overhead weight of the load. Box strength was probably the major cause of box failure, but moisture in the fiberboard may also have been a factor. Approximately 18.4 percent of the watermelons in these two loads were unsalable. Some of this loss was caused by shipping overmature melons.



PN-3248, PN-3249, PN-3250

FIGURE 21.—Arrival condition of watermelons in van containers, Florida to London, England, 1971: *Top*, palletized load in ventilated container; *center*, palletized load in refrigerated container; *bottom*, nonpalletized load in refrigerated container.

DISCUSSION

Grapefruit Test Shipments

The outturn condition of the grapefruit in the ventilated van test load was at least as good as that in the three refrigerated van containers. There was no box damage in the ventilated van container load, whereas 30 to 50 boxes were damaged in each of the refrigerated van container loads. Even though more boxes were carried in the ventilated van, transportation charges per box for the grapefruit in these test shipments were the same since there has been no ocean freight rate established for grapefruit shipped in ventilated van containers.

The overseas receiver of the shipments was very enthusiastic about the condition of the grapefruit received in the ventilated van container. He asked the shipper and USDA researchers when he could expect to receive regular shipments by this method. The answer depends on how soon such service with equipment of this type might be made available on the North Atlantic and North Pacific trade routes as an alternative service for shipping in refrigerated van containers.

Watermelon Test Shipments

The excellent arrival condition of the experimental load of watermelons in the ventilated van container as compared with the poor arrival condition of the loads in the two refrigerated van containers suggests that transporting the melons to overseas destinations may be feasible when (1) melons of the proper maturity in good condition are shipped, (2) sturdy, well-designed corrugated fiberboard boxes are used, (3) the melons and boxes are carefully selected, handled, and loaded with care, and (4) the ambient air temperatures are not too high and the supply of outside air to the cargo compartment of the container is adequately regulated.

General Discussion

Preliminary research was conducted on shipping perishable agricultural products that require medium temperature ranges in dry freight ventilated van containers, which were equipped with a waterproof ventilation system designed to admit sufficient air and to keep seawater out of the cargo compartment. The results showed that this is a feasible method of transporting these products to overseas markets when the ambient air temperatures at sea are low enough to cool the fruit without chilling it. The ambient air temperature on the North Atlantic for both grapefruit and watermelon shipments was satisfactory for cooling these loads.

The failure of the boxes in the refrigerated van container shipments paralleled experience with shipments of other commodities to both domestic and overseas markets. Apparently two factors contributed to this failure. First, the boxes used in the watermelon shipments were of lower test weight corrugated fiberboard, which provided less stacking strength to the boxes than the heavier test weight board used in the boxes in the ventilated van container shipment, especially under high humidity conditions. Second, shipping experiments with other products have suggested that paper bags and corrugated boxes used in shipments cooled with ambient air absorb less moisture than the same containers cooled by refrigeration. This experience suggests that when there is less spread between the cargo and ambient temperatures, the kraft paper used in such shipping containers will absorb less moisture from the air. Consequently, the containers retain more of their inherent strength under such shipping conditions.

Ocean carriers estimate that should shipment in ventilated van containers become an accepted method of transport, the ocean freight rate could be reduced at least 10 percent below rates for refrigerated van containers. The lower rate presumably would reflect the lower cost of providing transportation in the less expensive ventilated dry freight vans.

Dry freight vans even when converted to this ventilation system would have about 10 percent more usable cargo space than refrigerated vans because of less insulation in the

walls of the container and the gain of space occupied by refrigeration equipment in refrigerated containers. This extra cargo space was demonstrated with the heavier ventilated loads. A lower rate, coupled with less box damage and increased payload, could lower the overall cost to the shipper by approximately 15 percent for each load.

CONCLUSIONS

Limited experimentation with several types of waterproof ventilation systems for ventilated van containers indicates that it is possible to bring adequate quantities of ambient air into the cargo compartments of the containers for cargo cooling while at the same time keeping out seawater. With such a system the more plentiful, less costly dry freight van containers could be converted for overseas transport of selected perishable products that are now shipped in refrigerated van containers.

The results of this study indicate that ventilated van containers with the type of waterproof ventilation systems described here could be used successfully when good-quality, shippable products are carried. They also demonstrate that good-quality, well-designed shipping containers are essential, and careful packing, loading, and handling of the products and careful monitoring and control of the ventilation system during transport are necessary for success.

Use of such containers for overseas transport of selected perishables affords opportunities to reduce costs for the products. Such savings can be derived from lower freight rates for shipments made in ventilated containers that would reflect the lower cost of ownership and operation of such equipment as compared with the cost for the refrigerated containers. Some savings also should be gained from lower per-package freight costs that can result from shipping larger loads in the ventilated containers. The ventilated van containers can carry larger loads than the refrigerated containers because a greater amount of usable cargo space is available and the tare weight of the ventilated containers is less than that of the refrigerated containers.

At present the transport charges per box of products shipped in ventilated van containers are the same as for those shipped in refrigerated van containers. It is possible that lower charges for ventilated van containers shipments will be established after the ocean carriers have had some experience with them. Some carriers have estimated that such a reduction could amount to as much as 10 percent. Total potential savings in shipping charges per box with lower freight rates and increased load per container are estimated to be about 15 percent.

The favorable results of the preliminary research with this system of transporting perishables and its good reception by shippers and receivers warrant additional research to further refine the ventilation system and to develop guidelines for its use. Tests are needed over Pacific Ocean routes and additional research is needed to determine to what extent other perishable products could be successfully carried to overseas markets in equipment of this type. Some examples of refinement in the system that should be evaluated in future research are described in the appendix.

APPENDIX

Recommended Refinements in Equipment Design and Application

Air Exhaust Equipment

The exhaust blowers used in this study were mounted over two of the four vents on the outside of the rear doors and proved to be adequate. However, in regular commercial use they would be a hazard because of exposure to both water damage and breakage in loading and unloading the van containers.

A more practical method of using the ex-

haust blowers is to mount them on the inside of the rear doors immediately behind the vents. In this position the blowers would exhaust the air through the vents instead of pulling it through them as in this study. The outside hatch covers could then be closed to protect the blowers during bad weather or when the exhaust system was not in use.

Provision can be made for temporary attachment and removal of the exhaust blower equipment when the van container is assigned to and removed from perishable transport service. Such a system would produce greater flexibility in the use of the van containers. More such containers could then be assigned to perishable transport service in those seasons when ambient air temperatures at sea are sufficiently low to be used for cargo cooling. In addition, the exhaust blowers would be readily removable for off-season storage, service, and repair. Their temporary installation and removal would greatly reduce the number of exhaust blowers required and would result in increased utilization of the available supply.

The exhaust blowers could be easily mounted temporarily inside the rear doors by using lock tracks on each side of each vent and lock pins on the front of the exhaust blower housing (fig. 22). The lock tracks could be recessed into the lining of the rear doors so that the surface of the tracks would be flush with the inside surfaces of the doors. Such installation would help protect the lock tracks from damage.

To temporarily install the exhaust blowers in a van container equipped with lock tracks, two simple steps would be required. First, the lock pins on the front of the exhaust blower housing assembly would be inserted into the openings in the lock track. The entire assembly would then be moved to the left, in which position the lock pins would be in the lock track. The entire block assembly would then be pushed downward and to the right to lock it firmly into place against the door surface. The second step would be to plug the powerline from the blowers' electric motors into the electrical receptacle on the wall or ceiling of the van container. This receptacle carries the electric power from the thermostatically controlled relay at the front of the van container.

Air Temperature Control Equipment

The ambient air control system used in this study had one thermostat to open and close the

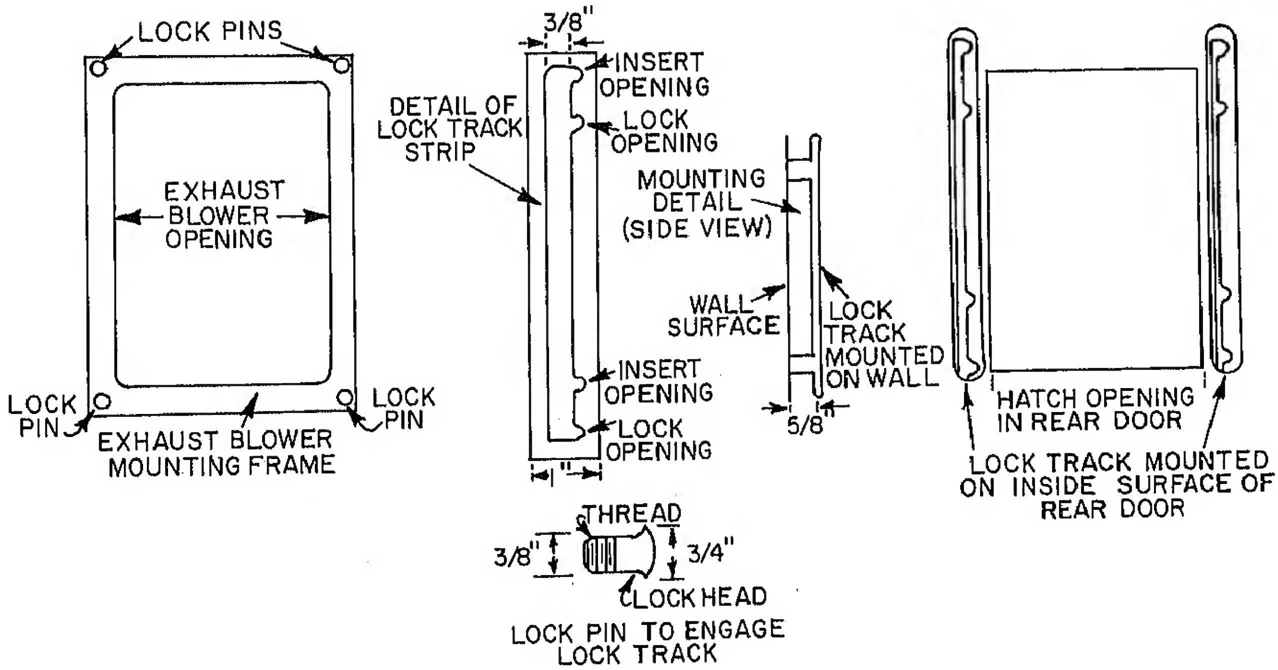


Figure 22.—Proposed exhaust blower mounting frame and track.

damper. The thermostat was activated by the temperature of the outside air entering the system. This control system prevents air cold enough to chill the fruit from entering the cargo compartment, but it does not provide for the removal of vital heat or heat of respiration generated by the product during prolonged periods when the damper is closed because the outside air temperature is lower than the thermostat setting. This deficiency might be overcome by installing a second control element. It would override the outside air control thermostat to open the damper and allow sufficient ambient air to enter the cargo compartment to remove some of the heat, but not so long as to chill the fruit.

A second method of providing for load cooling when the ambient air is cool enough to chill the fruit would be to use electric resistance heaters installed in the air supply system to add some heat to the incoming air. This system might be a more efficient way to control the temperature of the air supplied to the cargo compartment of the container, but it may present problems with insurance, border customs inspection regulations, or other requirements.

Shipping Temperature Data

Supplementary data on shipping temperatures are included in table 7.

TABLE 7.—*Average product and ambient air temperatures of 3 grapefruit shipments in refrigerated van containers by location in load, Florida to France, October 1970* [1]

Days after loading	Product temperature					Ambient air temperature	Average thermostat setting
	Top	Bottom	Center	Right wall	Left wall		
	° F.	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
SHIPMENT 1							
Start	81	80	81	81	81	80	60
5th	60	62	61	60	61	57	60
6th	62	63	62	62	62	60	60
7th	62	62	62	62	62	65	60
8th	63	64	64	63	62	63	60
9th	63	64	64	63	63	47	60
10th	61	62	60	60	60	50	[2] 57
11th	60	61	60	60	60	53	57
12th	62	63	63	63	62	56	57
13th	63	63	63	63	63	56	57
14th	60	62	61	60	60	55	[2] 54
15th	58	59	60	58	58	52	54
SHIPMENT 2							
Start	80	77	80	80	81	80	60
5th	57	58	60	58	58	57	60
6th	58	57	58	57	58	60	60
7th	58	58	58	59	58	65	60
8th	59	61	60	60	59	63	60
9th	61	61	61	60	60	47	60
10th	60	60	61	60	61	50	60
11th	60	60	60	60	61	53	60
12th	62	62	62	62	62	56	60
13th	62	62	63	62	62	56	60
14th	59	60	60	60	59	55	[2] 56
15th	57	58	58	58	58	52	56
SHIPMENT 3							
Start	81	81	81	81	81	80	60
5th	59	60	59	60	59	57	60
6th	60	60	60	60	60	60	60
7th	60	61	61	61	61	65	60
8th	61	60	61	61	60	63	60
9th	61	60	60	60	60	47	60
10th	60	60	60	60	60	50	60
11th	60	61	60	60	60	53	60
12th	61	62	62	61	62	56	60
13th	62	63	63	62	63	56	60
14th	59	61	60	60	60	55	[2] 56
15th	54	55	54	54	54	52	56

[1] Each of the top, bottom, right wall, and left wall readings is an average of 3 locations; center is average of 6 locations in center of load. (See fig. 16.)

[2] Thermostat reset.

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